

CLAIMS

What Is Claimed Is

- 1 1. A device comprising:
2 one or more acceleration measuring transducers to be positioned around a user's torso
3 to detect the user's movement in one or more axes, at least one of the acceleration
4 measuring transducers to provide an output signal corresponding to motion along
5 one axis;
6 an altimeter to detect changes in altitude and provide a corresponding output signal;
7 and
8 a processing unit communicatively coupled to the plurality of acceleration measuring
9 transducers and the altimeter, the processing unit to receive one or more signals
10 from the one or more acceleration measuring transducers and the altimeter and
11 generate navigation information.

- 1 2. The device of claim 1 wherein the processing unit is configured to use the one or more
2 acceleration signals and altimeter signal to
3 determine a nominal stride length,
4 deduce a type of step taken by a user,
5 determine a scaling multiplier for the deduced type of step, and
6 apply the scaling multiplier to the nominal stride length to estimate the correct
7 distance traveled.

- 1 3. The device of claim 1 wherein the processing unit is configured to determine the slope of
2 motion by
3 determining the number of steps taken by the user,
4 determining the horizontal distance traveled by multiplying the number of steps by a
5 nominal stride length,
6 determining a change in elevation from the altimeter signal, and
7 dividing the change in elevation by the horizontal distance traveled.

1 4. The device of claim 3 wherein the processing unit is configured to use the slope
2 information select a scaling multiplier to adjust the nominal stride length for purposes of
3 accurately calculating distance traveled.

1 5. The device of claim 1 further comprising:
2 one or more magnetometers capable of sensing the earth's magnetic field, at least one
3 magnetometer communicatively coupled to the processing unit to provide a signal
4 corresponding to the direction of earth's magnetic field.

1 6. The device of claim 1 wherein the processing unit is configured to
2 determine acceleration changes over time from the one or more acceleration signals to
3 determine an approximate direction of motion.

1 7. The device of claim 1 wherein the processing unit is configured to distinguish a either a
2 forward or backward step movement from a sideways step movement.

1 8. The device of claim 7 wherein the one or more acceleration measuring transducers
2 include

3 a forward/backward axis accelerometer providing a forward/backward
4 acceleration signal,
5 a transverse axis accelerometer positioned approximately perpendicular to the
6 forward/backward axis accelerometer and providing a transverse acceleration
7 signal, and

8 wherein the processing unit is configured to distinguish between a forward or
9 backward step movement from a sideways step movement by

10 calculating the square of the forward/backward acceleration signal to
11 generate a variance,

12 calculating the square of the transverse acceleration signal to generate a
13 variance,

14 calculating a covariance by multiplying the forward/backward acceleration
15 signal by the vertical acceleration signal,

16 testing for correlation by multiplying the forward/backward-vertical
17 covariance by the forward/backward variance.
18 determining a frequency of the walking steps for a user,
19 passing the variances and variance/covariance product through low-pass
20 filter with a cut-off frequency approximately the frequency of walking steps for a
21 user,
22 comparing the filtered forward/backward and transverse variances at a
23 moment of step detection, and
24 if the transverse covariance exceeds the forward/backward variance by
25 a pre-determined ratio, a sideways step is assumed,
26 otherwise, if the variance/covariance product exceeds a threshold, a
27 forward step is assumed, otherwise a backward step is assumed.

1 9. The device of claim 1 wherein the one or more acceleration measuring transducers
2 include

3 a transverse axis accelerometer positioned approximately perpendicular to the
4 forward direction of motion and providing a transverse acceleration signal, and
5 wherein the processing unit is configured to distinguish the direction of a sideways
6 step motion by monitoring characteristics of the transverse acceleration signal.

1 10. The device of claim 1 wherein the processing unit is configured to identify a running
2 motion and adjust a nominal stride length to accurately account for distance traveled.

1 11. The device of claim 10 wherein the one or more acceleration measuring transducers
2 include

3 a vertical axis accelerometer providing a vertical acceleration signal,
4 wherein the processing unit is configured to compensate for a running motion by
5 determining a difference between a maximum and minimum instantaneous
6 vertical acceleration values within a most recent one step cycle,
7 dividing this difference by the time elapsed over the most recent one step cycle,
8 and

9 if the quotient is greater than a threshold, a running motion is assumed and the
10 nominal stride length is increased proportionally for purposes of dead reckoning
11 calculations.

1 12. The device of claim 1 wherein the processing unit is configured to distinguish a forward
2 step movement from a backward step movement based on the signals from the one or more
3 acceleration measuring transducers.

1 13. The device of claim 12 wherein the one or more acceleration measuring transducers
2 include

3 a forward/backward axis accelerometer providing an instantaneous
4 forward/backward acceleration signal,
5 a vertical axis accelerometer providing an instantaneous vertical acceleration
6 signal,

7 wherein the processing unit is configured to distinguish a forward step movement
8 from a backward step movement by

9 calculating a variance by taking the square of the forward acceleration
10 signal,

11 calculating a covariance by taking the product of the forward acceleration
12 signal and the vertical acceleration signal,

13 calculating the instantaneous arithmetic difference between forward
14 variance and forward-vertical covariance,

15 if, at the moment a step is detected, the difference is smaller than a
16 threshold, the step is assumed to be a backward step,

17 otherwise, a forward step is assumed.

1 14. A method for navigating on foot comprising:
2 monitoring one or more acceleration sensors arranged mounted at a user's torso to
3 measure acceleration along different axes; and
4 analyzing the acceleration changes over time to determine an approximate direction
5 of movement with respect to a first direction.

1 15. The method of claim 14 further comprising:
2 measuring acceleration changes over time to determine the approximate change in
3 distance between the user's steps due to a running step versus a walking step.

1 16. The method of claim 14 further comprising:
2 estimating the distance traveled between user steps based on the approximate direction of
3 motion relative to a heading and slope.

1 17. A method comprising:
2 monitoring one or more accelerometers aligned along one or more axis;
3 generating a signal corresponding to the acceleration sensed along the corresponding
4 axis;
5 monitoring an altimeter for an elevation signal;
6 deducing a type of step taken by a user, based on one or more of the acceleration
7 signals;
8 determining a stride scaling multiplier for the deduced type of step; and
9 scaling the nominal stride length with the scaling multiplier to estimate the correct
10 distance traveled.

1 18. The method of claim 17 further comprising:
2 determining the number of steps taken by the user;
3 determining the horizontal distance traveled by multiplying the number of steps by a
4 nominal stride length;
5 determining a change in elevation from the altimeter signal; and
6 dividing the change in elevation by the horizontal distance traveled to obtain the slope
7 of the terrain traveled.

1 19. A method to distinguish between a forward step and a sideways step comprising:
2 monitoring a forward acceleration signal;
3 monitoring a transverse acceleration signal, the transverse acceleration direction
4 being perpendicular to the forward acceleration direction;

calculating the square of the forward/backward acceleration signal to generate a variance;
calculating the square of the transverse acceleration signal to generate a variance;
calculating the product of the forward/backward acceleration and the vertical acceleration to generate a covariance;
determining a frequency of the forward walking steps for a user;
passing the variances and covariance through low-pass filters with a cut-off frequency approximately the frequency of forward walking steps for a user;
comparing the filtered forward/backward variance and transverse variances at a moment of step detection; and
assuming a sideways step if the transverse variance exceeds the forward/backward variance by a ratio.

20. A method for distinguishing between right and left directions of travel, comprising:
monitoring a transverse acceleration signal, the transverse acceleration direction being perpendicular to the forward/backward acceleration direction; and
distinguish the direction of a sideways step motion by monitoring characteristics of the transverse acceleration signal.

21. A method for estimating distance traveled on foot, comprising:
identifying a running motion by
monitoring vertical acceleration,
determining a difference between a maximum and minimum instantaneous vertical acceleration values within a most recent one step cycle,
dividing this difference by the time elapsed over the most recent one step cycle;
and
if the quotient is greater than a threshold, adjusting a nominal stride length to accurately account for distance traveled by multiplying the nominal stride length by a proportional scaling multiplier to accurately account for the distance traveled.

1 22. A method for distinguishing between forward steps and backward steps, comprising:
2 monitoring a forward/backward axis accelerometer;
3 monitoring a vertical axis accelerometer;
4 calculating a variance by taking the square of a forward/backward acceleration signal;
5 calculating a covariance by taking the product of the forward/backward acceleration
6 signal and a vertical acceleration signal;
7 determining the product of the forward/backward variance and the forward/backward-
8 vertical covariance;
9 assuming a backward step if, at the moment a step is detected, the product is smaller
10 than a threshold; and
11 otherwise, assuming a forward step.